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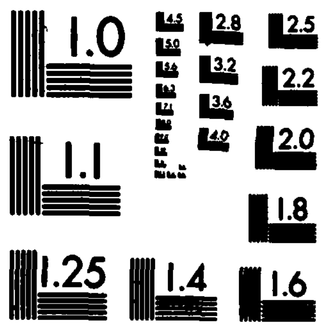
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ANALYSIS OF THE FLOW FIELD ABOUT A T-45 USING PANAIR

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This report summarizes the work accomplished while utilizing PANAIR to predict the wing pressure distributions on the T-45 Hawk aircraft and then comparing these data to experimental wind tunnel results. The T-45 aircraft is part of a new Navy training system that will provide fixed wing jet flight training for intermediate and advanced phases of the Navy Integrated Flight Training System (NIFTS) to meet future pilot production requirements. Comparisons of the theoretical predictions obtained from PANAIR with experimental results show excellent agreement between the two data sets.

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TABLE OF CONTENTS

LIST OF FIGURES

SUMMARY

The Naval Air Development Center is in the process of applying state-of-the-art CFD (Computational Fluid Dynamics) analysis techniques to Navy aircraft under an IR program (reference a). This effort required the acquisition and evaluation of numerical codes which predict the behavior of aircraft under various flight conditions. As the first task under this investigation the panel program PANAIR was acquired and implemented on the Naval Air Development Center CDC 175 Computer. After developing an operational capability with the program, an analysis of a complete aircraft configuration was performed.

This report summarizes the work accomplished while utilizing PANAIR to predict the wing pressure distributions on the T-45 Hawk aircraft and then comparing these data to experimental wind tunnel results. The T-45 aircraft is part of a new Navy training system that will provide fixed wing jet flight training for intermediate and advanced phases of the Navy Integrated Flight Training System (NIFTS) to meet future pilot production requirements. Comparisons of the theoretical predictions obtained from PANAIR with experimental results show excellent agreement between the two data sets.

INTRODUCTION

The rapid advances which are occurring in computer technology have had a significant effect upon the procedures which engineers employ to design practical systems. As an example it is to be noted that aerodynamics problems previously considered computationally unattainable have become almost routine. Both the academic and industrial communities are contributing to this evolution in numerical computation techniques. The technology is moving so rapidly that many new research codes are being developed for various regions of aerodynamic analysis.

In view of these developments the Naval Air Development Center is conducting an IR program to acquire, implement and evaluate the best available codes for the solution of problems that apply to Navy unique vehicle configurations. The purpose of this task would be the integration of these research codes into practical design tools for investigation of many flow regions and conditions. Further, it will be necessary to perform sufficient comparisons with experimental data to validate that the computational codes are operating in the manner that was originally intended.

PURPOSE

It is the purpose of this report to document the work performed in utilizing the linear inviscid flow program called PANAIR on the analysis of the T-45 Hawk aircraft. This report summarizes the excellent agreement possible when using PANAIR to predict model pressure data in a wind tunnel at low Mach numbers. The Naval Air Development Center, under this IR program, is attempting to transition computational fluid dynamics research codes into practical and useful design/analysis tools. to Form 1473

OBJECTIVE

In this report the objective is to summarize the current progress in employing linear inviscid panel codes in the solution of Navy aircraft problems. Work on the T-45 has shown that it is possible for the Navy to perform a complete analysis of an entire aircraft in the low Mach number range. This analysis will be extended to high Mach numbers to show that the computational models are capable of predicting transonic and supersonic performance of Navy aircraft.

DISCUSSION

The Naval Air Development Center is developing capability in the area of applied computational aerodynamics. Because this area of research is receiving a great deal of industrial emphasis, many codes have been developed which permit the analysis of different regions of fluid behavior, i.e., subsonic, transonic, supersonic and hypersonic.

After an initial investigation of the available computational fluid dynamics methodology it was decided that a panel method program would best serve as the basic computational element. Since in the initial phases of this project the primary concern is predicting the subsonic performance of Naval aircraft, a decision to acquire an inviscid code would lead to the greatest initial operational capacity. Although there are several operational inviscid codes in existence Boeing Company's PANAIR (reference b, c, d) appeared to best satisfy in-house Navy operational requirements. This particular code provides solutions to the Prandtl-Glauert equation, i.e.,

$$(1-M_\infty^2)\frac{\partial^2\Phi}{\partial X^2}+\frac{\partial^2\Phi}{\partial y^2}+\frac{\partial^2\Phi}{\partial Z^2} = 0$$

where M_∞ = Mach number at infinity

X = coordinate direction coincident with distant flow

y, Z = coordinates perpendicular to distant flow

Φ = potential function

Panel methods determine solutions to the above equation by utilizing sources and doublets, i.e., singular solutions, of unknown magnitude which are imbedded in the configurational surface of the vehicle under consideration. Precise adjustment of the magnitudes of these quantities, by the computer software, may be made to yield the inviscid flow field corresponding to the arbitrary spatial arrangement under consideration. Since PANAIR employs higher order numerical techniques, it is less sensitive to the particular paneling procedure adopted by the investigator. Further, this computational algorithm is capable of determining flow field behavior in the supersonic region, i.e., between Mach numbers of 1.3 to 1.8. Obviously the accuracy and flexibility inherent in this code is the reason for the larger operational costs; however, in view of the continual decrease in computer costs this constraint will eventually disappear.

After completing an analysis of the available panel codes a copy of the PANAIR program was acquired. As the first step in determining the computational integrity of the code, selected sample cases were run and evaluated. Comparisons of the results with the information supplied by Boeing personnel from their solution of the identical problems proved that the code was operating correctly. Next it was desired to obtain an understanding of the code's performance under operational conditions (reference e.) To satisfy this objective an investigation of three panelings of the unit sphere, i.e., 16, 64 and 128 panels, was conducted. Since the sphere possesses an exact solution to zero Mach number, an absolute measure of the accuracy of the code versus panel density was obtained. Indeed, numerical comparison, reference (e) of the PANAIR results with the theoretical solution indicated excellent agreement between the two data sets provided the code was supplied with a proper model. Since the sphere exhibits a blunt profile to the flow and the Mach number approximates values exhibited by airships, the initial study was followed by an application to an airship. Very good experimental information obtained in Germany over fifty years ago, was available on the

Hindenburg for comparison purposes. Thus, an analysis of the German airship Hindenburg was initiated since its experimental data base was as extensive in scope as was necessary for evaluation purposes. In reality the German results represented pressure measurements taken during wind tunnel tests of a model measuring 24 meters in length. Further, these data reflect the behavior of the basic form of the airship, i.e., there was no attempt to characterize the tail surfaces, propulsion system, etc. of the vehicle. Again a sequence of three distinct panelings of the object, i.e., Hindenburg, were constructed and the resulting models were subjected to analysis using PANAIR. This latter set of studies, reference (e), showed that flow analysis with the present instrument is relatively insensitive to paneling density provided a sufficient number of panels are included in the representation of the physical system. Indeed, all experience indicates that relatively reliable results may be obtained provided reasonable care is exercised in utilizing the program.

Having acquired sufficient experience in the operation of the code to be certain of the computational results it was decided to investigate a complete aircraft configuration. However, it is important to recognize that this task was needed to establish operational techniques which were not at variance with the modeling requirements imbedded in the PANAIR code. Therefore, an example had to be selected which would validate the capability of operating the code to obtain meaningful engineering data. To insure the quality of the results, it was also desirable to investigate a system for which accurate experimental data existed.

At the present time the Navy is in the process of acquiring the T-45 Hawk aircraft as part of a new training system for pilots to replace the T-2B/C and TA-4J trainer aircraft. In view of the Navy's interest in this particular aircraft, it was decided to employ the Hawk as the next application study aircraft.

Several wind tunnel tests have been performed on the Hawk. Available experimental information included wing pressure data implying that a reasonably complete comparison of the predictions of PANAIR with experiment could be performed.

REPRESENTATION OF THE PHYSICAL SYSTEM

The central problem in performing a complete analysis of any aircraft is the development of a valid numerical representation of that vehicle. This task requires the construction of a sequence of computer programs and their integration into a procedure which will perform certain functions.

Models for the PANAIR program are produced by subdividing the surface of the aircraft model into sequences of rectangles. These rectangles or panels form the basic computational elements in the PANAIR program. One defines the extent of each panel by prescribing the position of the four corner points of the rectangle. In the regular procedure the four panel corner points, i.e., a portion of an aircraft fuselage, etc., are input by interpolating given engineering configurational data. Junctions formed by the intersection of the wing, horizontal and vertical tail with the fuselage are generated by a software package called PABS. Since information on the spatial configuration of the Hawk was acquired from the Douglas Aircraft Company in digital form, the geometric data for the model was entered manually. An in-house developed program was utilized to transform the PANAIR input data format to be compatible with HAB'S, i.e., a graphic plot routine, input format. Next HABS was employed to display the geometric form defined by the PANAIR input file in order to check the consistency of the input information. This particular graphic routine allows the user to enlarge any portion of the figure under examination for detailed inspection. In this manner, most of the initially input geometric errors can be detected and corrected before an attempt to perform a PANAIR run. Insuring the fidelity of the computational construct is significant when considering

the quality of the output data. Small geometric errors can produce gaps in the representation of the aircraft and these elements can seriously alter the local flow field and degrade the accuracy of the computed velocity components.

After the computer run is accomplished, an in-house developed computer program, PANREAD is employed to read the PANAIR output file. This output data is then transformed into the input format of a plot routine called UTABS. Finally, the computed results are plotted so as to conveniently summarize the essence of the numerical output. If need be, UTABS is sufficiently flexible to admit the plotting of experimental data lists simultaneously with the computed results.

As previously mentioned numerical information on the configuration of the Hawk was acquried from the Douglas Aircraft Company. Most of these data consisted of digital descriptions of the fuselage and wing contours corresponding to fixed stations along the aircraft fuselage and wing. For purposes of completeness it is of importance to observe that this information was employed to fabricate two distinct representations of the Hawk. Specifically, one of these models would depict the complete Hawk while the other construct removed all of the tail assemblies. The wind tunnel model used to ascertain the pressure distribution across several wing stations did not possess a tail assembly. Thus, the computational model attempted to exactly reproduce in a mathematical sense the physical situation which existed in the wind tunnel during the experimental tests. In this regard it is necessary to note that the experimental equipment permitted air flow through its interior. Therefore, the computational configuration was constructed to admit flow through the engine inlets. Figures 1 and 2 depict the two versions of the Hawk which were developed. Although no computational work was performed with the complete version of the Hawk, this model was constructed so that we could investigate the complete configuration at a later time. The previously mentioned figures were computer drawn utilizing the input data supplied to PANAIR, hence, they depict the actual configuration under analysis. Further, it should be noted that the wakes adopted to satisfy the Kutta condition have been deleted from the figures. Unfortunately the addition of these quantities to the representation would obscure some of the details of the physical system so that the wakes were removed to insure clarity of the resulting diagram. However, it is conceptually necessary to record that the wakes were located at the trailing edge of the wing, along the lower fuselage to the rear of the wing and around the end of the aircraft so that the exhaust was confined to a typical plume like domain.

EXPERIMENTAL DATA

Experimental observations of the behavior of the model of the Hawk were obtained while the onset flow was held at a Mach number of 0.2. Of particular relevance for the present study was the fact that the empirical information included pressure measurements along four wing stations corresponding to four different angles of attack. Specifically, the pressure data was recorded at 25, 47, 69.5 and 87.5 percent semispan along the wing corresponding to angles of attack of -2., 4.31, 14.28 and 16.78. In the PANAIR model, the panels were constructed in a regular fashion to insure numerical stability of the computational output and, therefore, the physical location of the two data sets does not coincide. Thus, although the Mach number and angles of attack were made to correspond exactly between the experimental system and the PANAIR model the stations at which the pressures were determined are different. Therefore, it was necessary to interpolate one of the two sets of data so that the results could be compared at identical wing station locations. The PANAIR data was interpolated linearly along the span of the wing to bring the data sets into coincidence. Although this linear operation will somewhat distort the non-linear function, i.e., the coefficient of pressure, this procedure should not seriously effect the comparisons between theory and experiment.

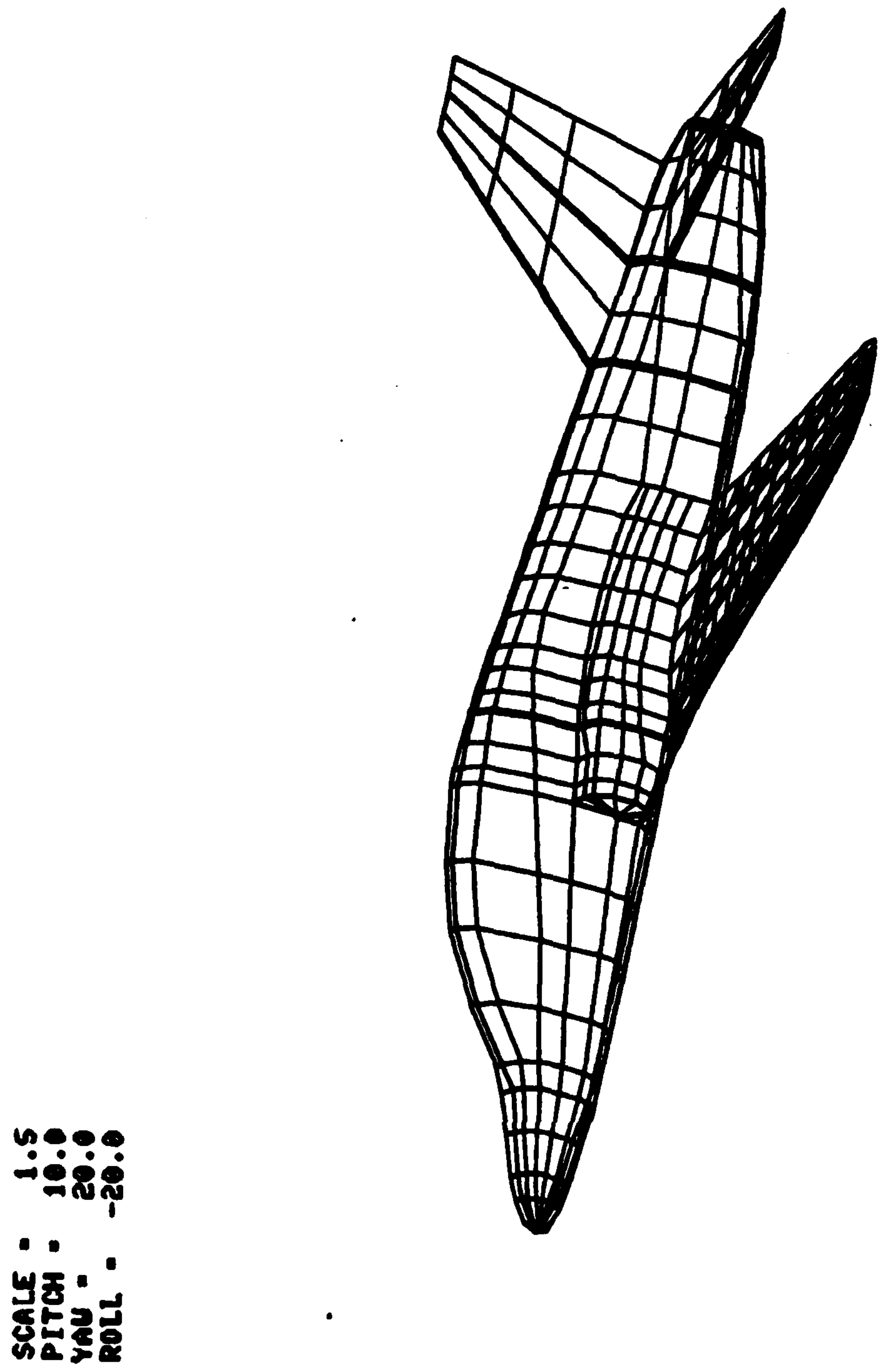

Figure 1. Complete Model of T45

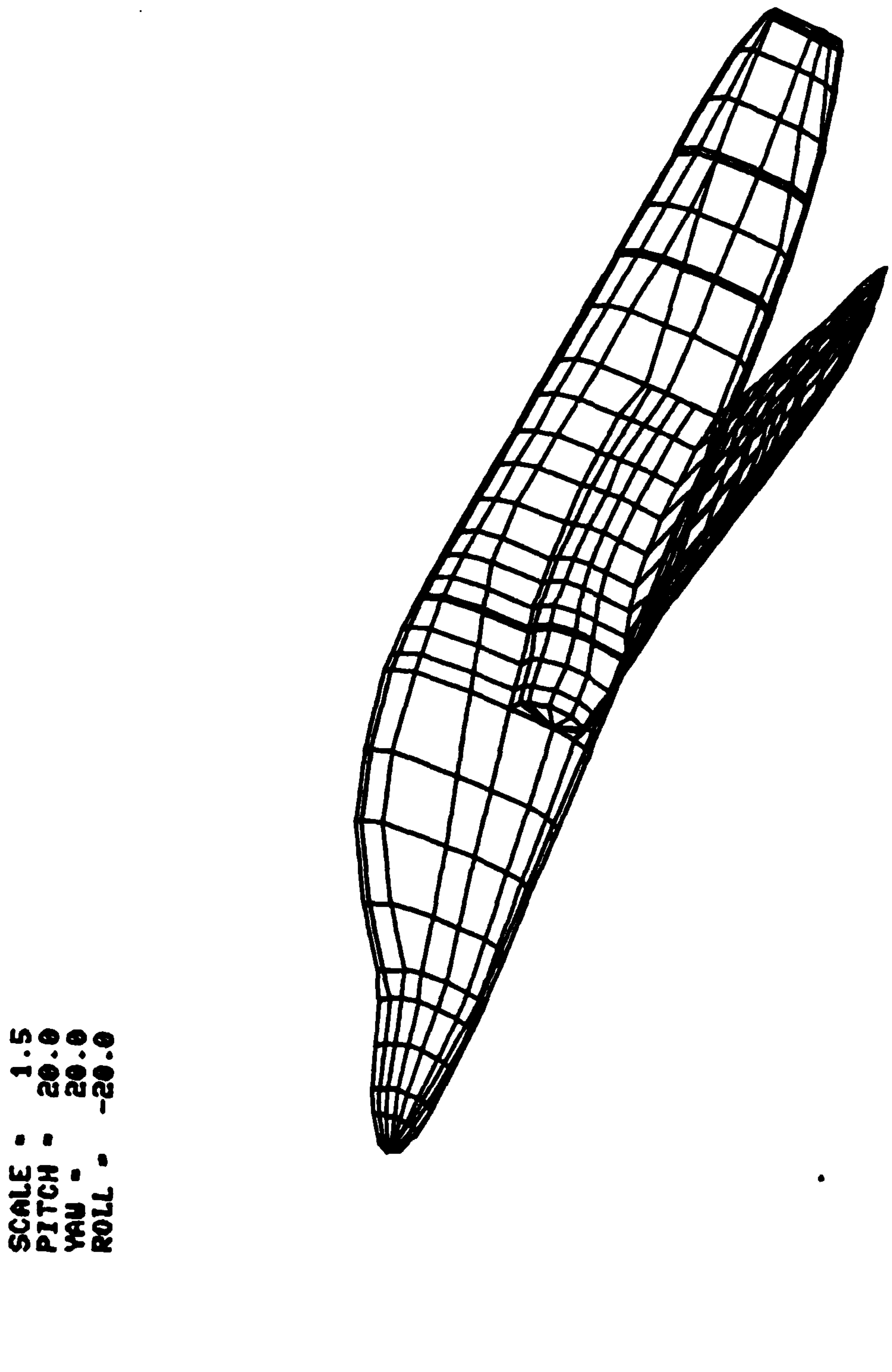

Figure 2. Wind Tunnel Test Model of T45

COMPARISON OF THEORY AND EXPERIMENT

The experimental and analytical results are compared in figures 3 through 18. In the case of the 69.5 percent semispan station the two sets of points were physically identical so that interpolation of the PANAIR data proved unnecessary. Thus, this data set provides the best direct comparison between theory and experiment. Inspection of figures 11, 12, 13 and 14 indicates an excellent agreement between the two data sets except in the region of the first several percent of the wing. Of course, this type of behavior is to be expected since we are utilizing a linear small perturbation theory and in the forward part of the wing the perturbations must be large since a stagnation point is located in the region. PANAIR does include an ability to empirically correct computational data in this domain, however, at this stage it was important to generate unmodified PANAIR data. Corrections for the presence of a stagnation point will be employed after testing of the basic PANAIR procedures has been completed. Figures 3 through 10 and 15 through 18 summarize the identical information provided by the previous four figures but corresponding to the three other semispan locations, i.e., 25%, 47% and 87%. These remaining figures also indicate excellent agreement between the experimental and analytic data sets. Thus, it may be concluded that the linear interpolation procedure does not seriously distort the representation of the data. Indeed, only for the 25 percent semispan station does the agreement between theory and experiment degrade. This, of course, is a consequence of the fact that it is located near the fuselage. Certainly the characteristics of the wing-fuselage interaction are such that its effects on the inboard sections of the wing should be observable in the experimental data. Unfortunately, a pure inviscid treatment of these actions is not adequate so that one would suspect the PANAIR data without some correction for viscous effects.

The really excellent agreement between the two data sets at the large angles of attack, i.e., 14.28 and 16.78, is surprising. One would normally expect that separation would have been initiated and, thus, the inviscid flow field would not have been applicable at such a large angle of attack. Certainly the wing design in the low Mach number region is exceptional. Boundary layer investigations have not progressed to the point where an analysis of this particular wing is possible. However, at a later time a follow-on investigation of the physical reasons for the excellent agreement between theory and experiment at the large angles of attack will be conducted.

CONCLUSIONS

The Naval Air Development Center is in the process of applying state-of-the-art computational procedures to Navy aircraft under an IR program. As the first step in achieving this goal we have acquired and implemented the linear inviscid code known as PANAIR. Numerical experiments have been performed in order to obtain an operational capacity with this code. This work has led to the computational analysis of a complete aircraft. This investigation has shown that the capability exists to determine the flow field about a complete aircraft in the low Mach number region. As experimental information becomes available it is intended to prove that this capability is extendable to the higher Mach number range of subsonic flows, i.e., corresponding to operational velocities.

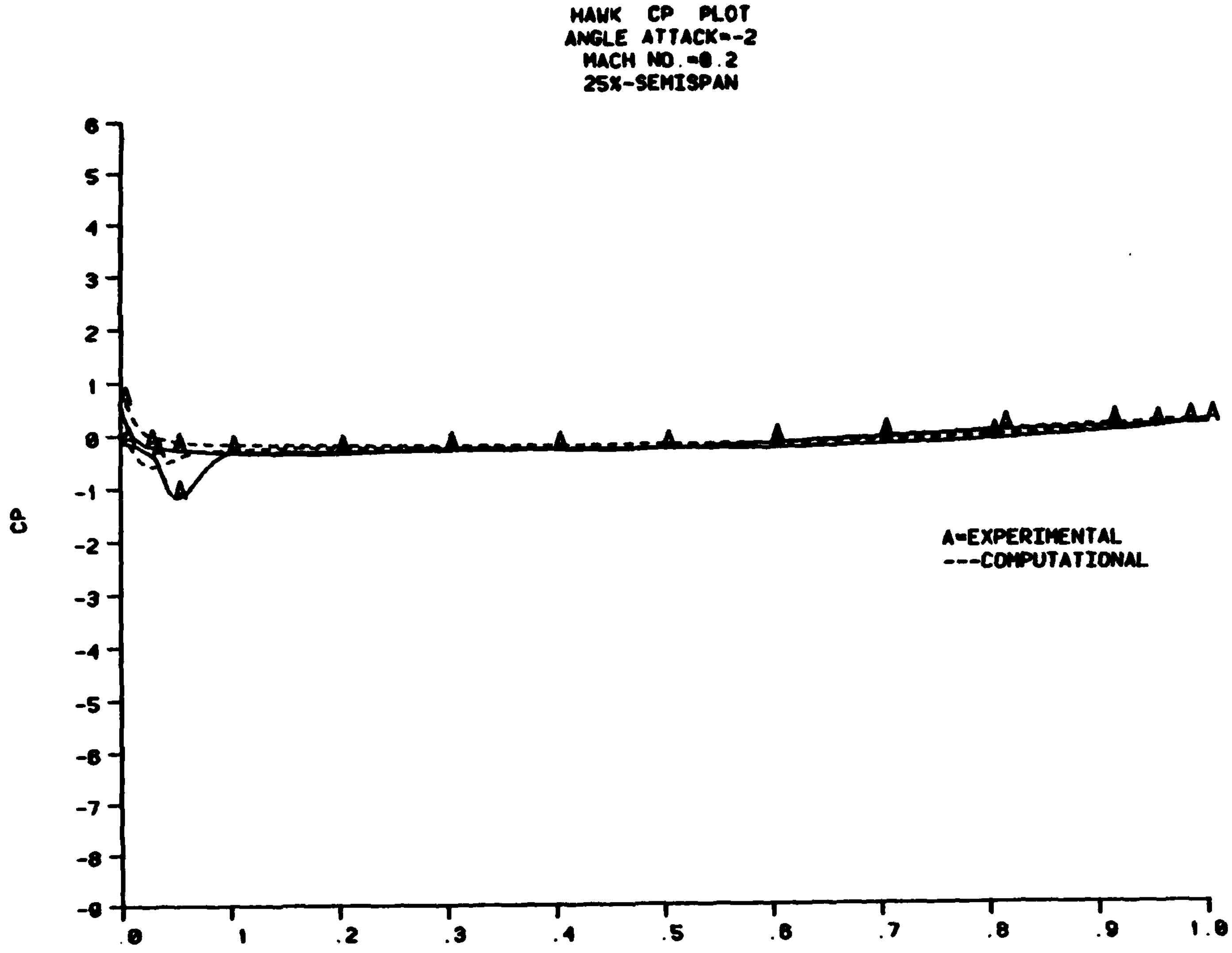

Figure 3. Comparison of CP Distribution at 25% Semi Span at -2° Angle of Attack

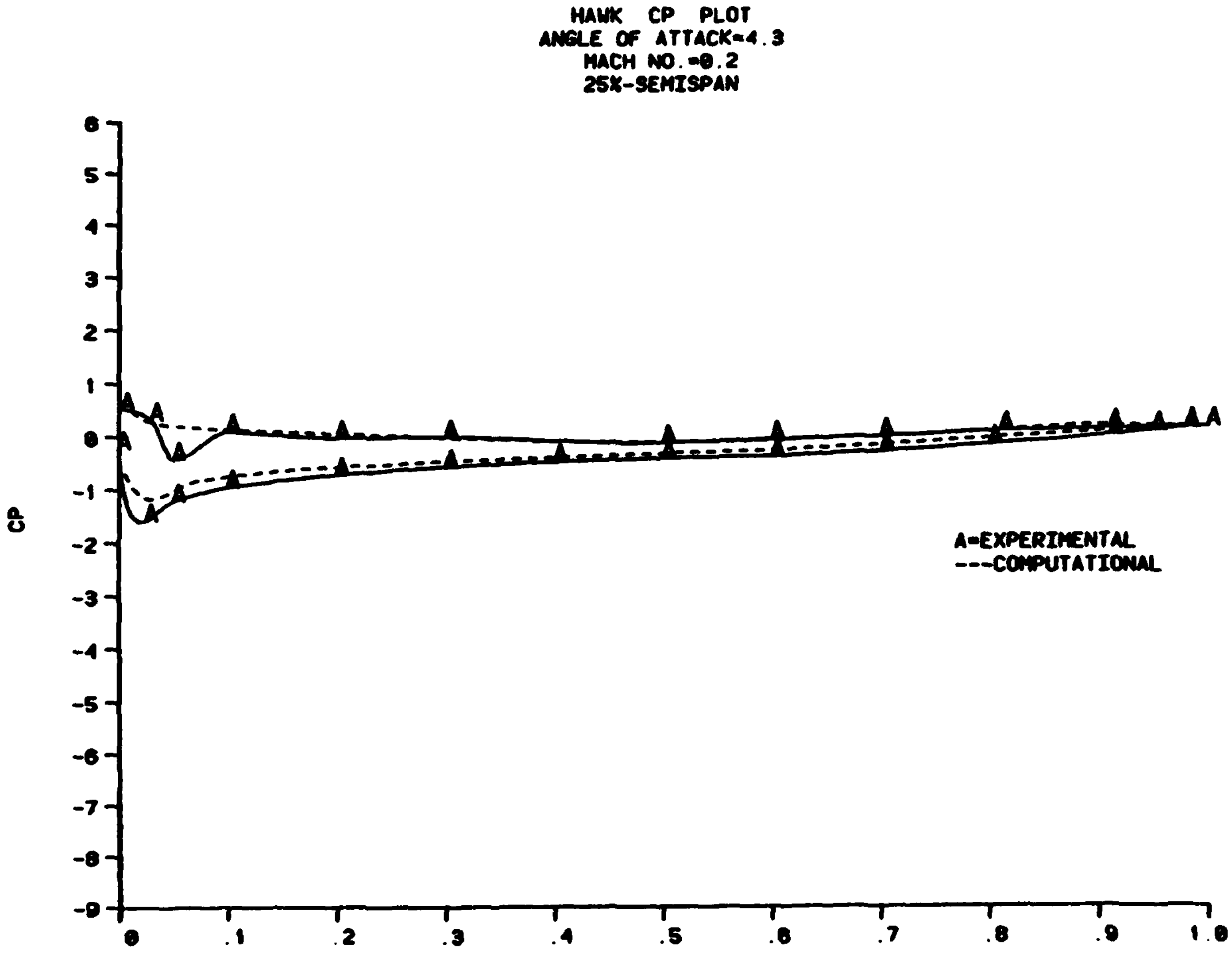

Figure 4. Comparison of CP Distribution at 25% Semi Span at 4^{O} Angle of Attack

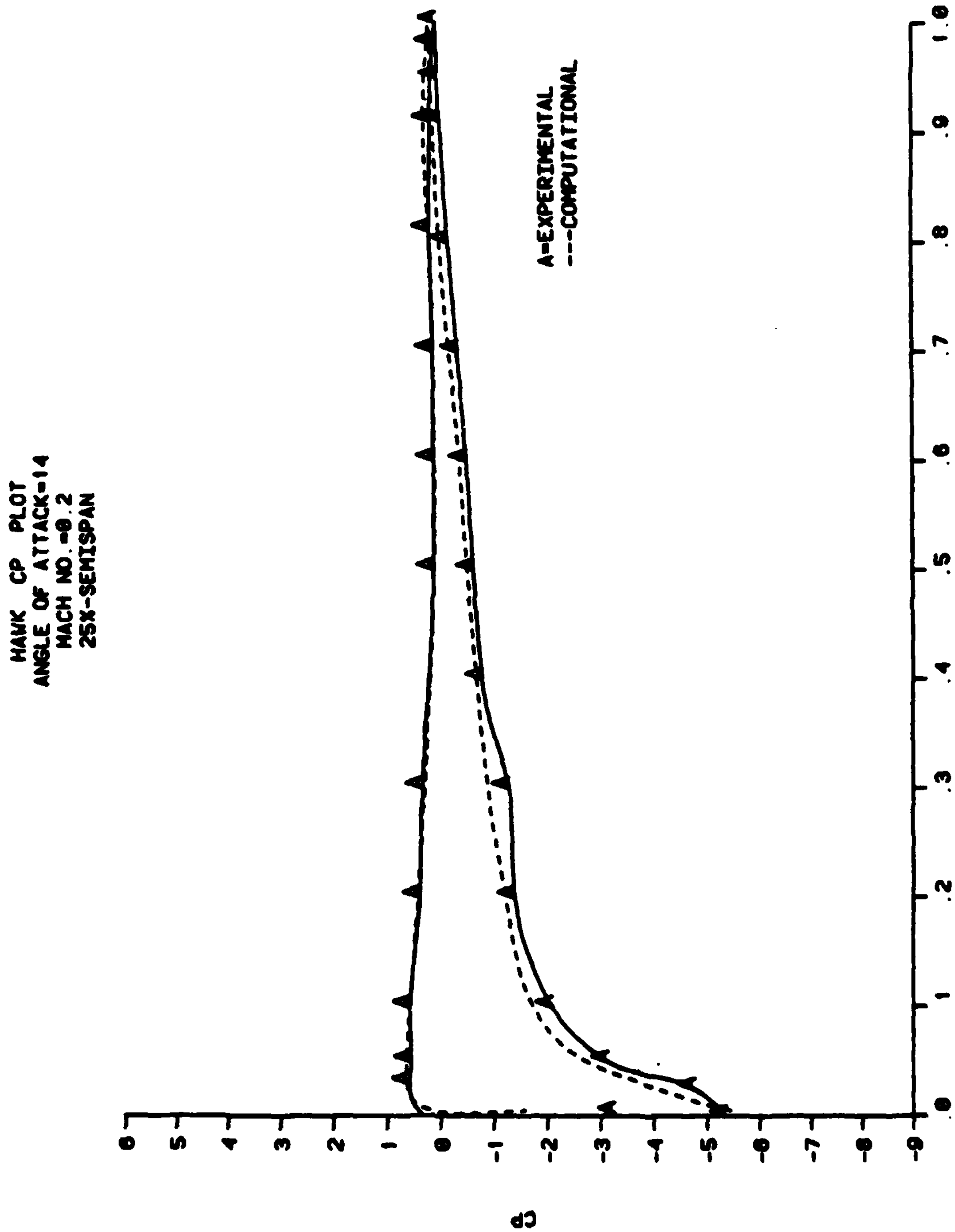

Figure 5. Comparison of CP Distribution at 25% Semi Span at 14^{o} Angle of Attack

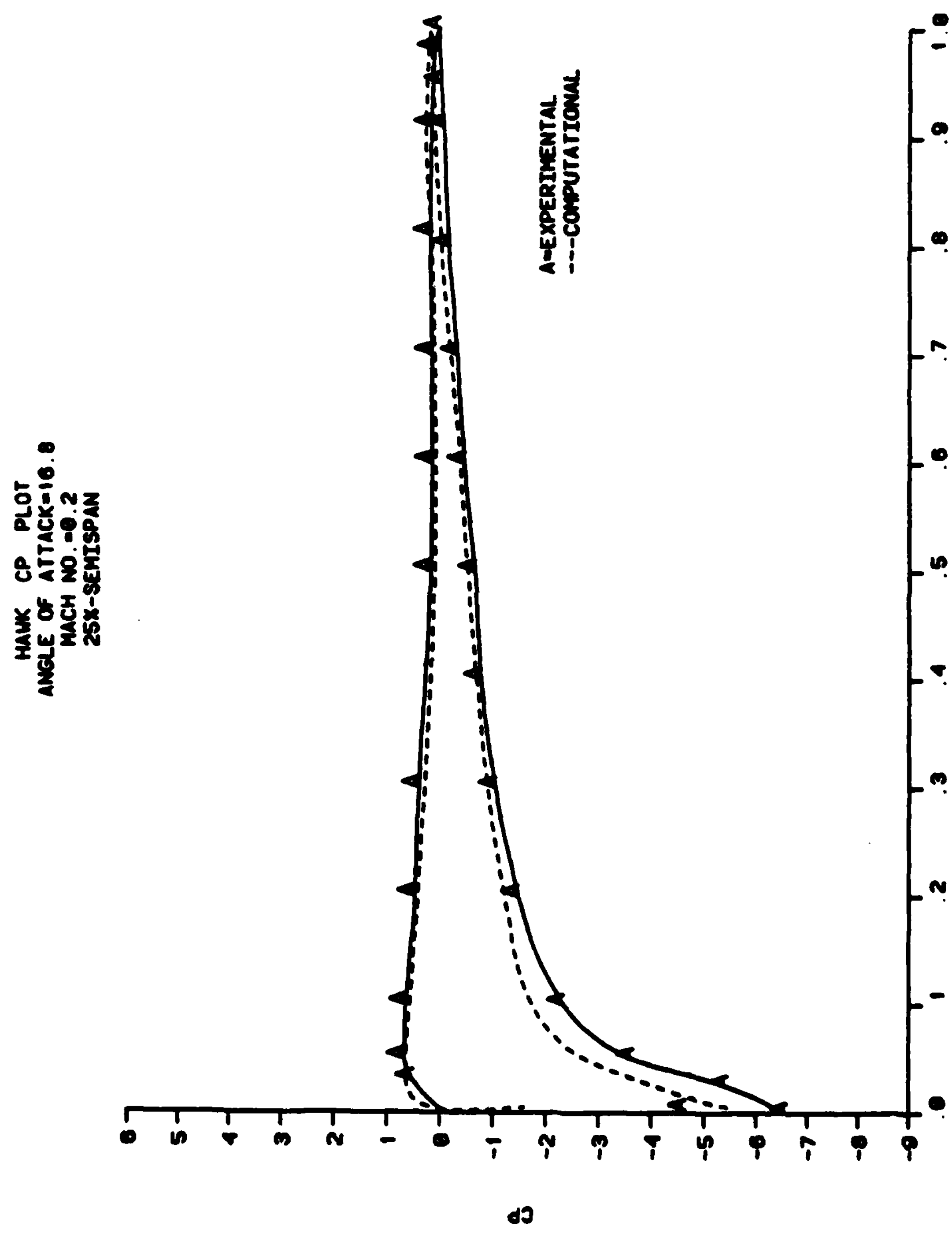

Figure 6. Comparison of CP Distribution at 25% Semi Span at 16.8° Angle of Attack

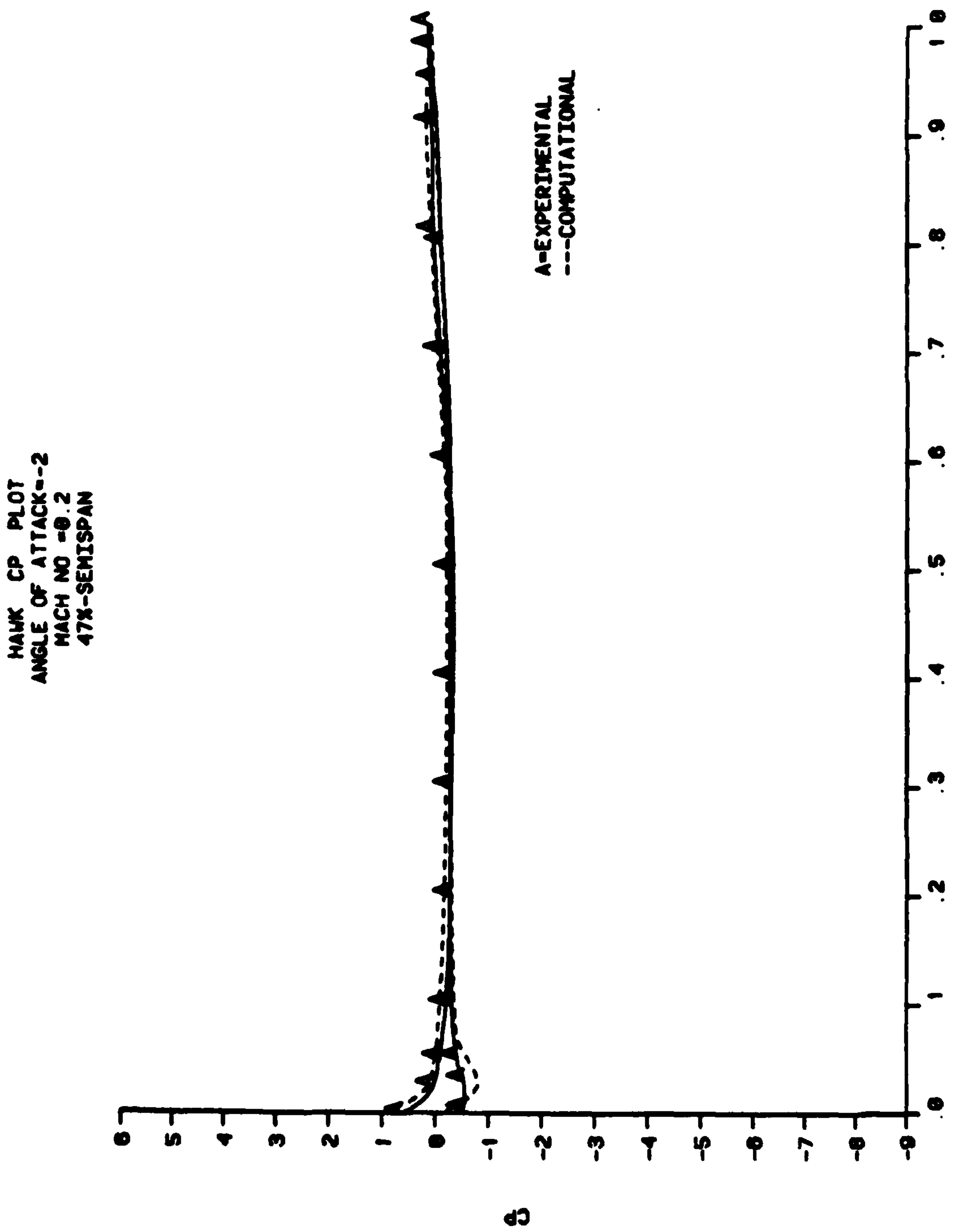

Figure 7. Comparison of CP Distribution at 47% Semi Span at -2° Angle of Attack

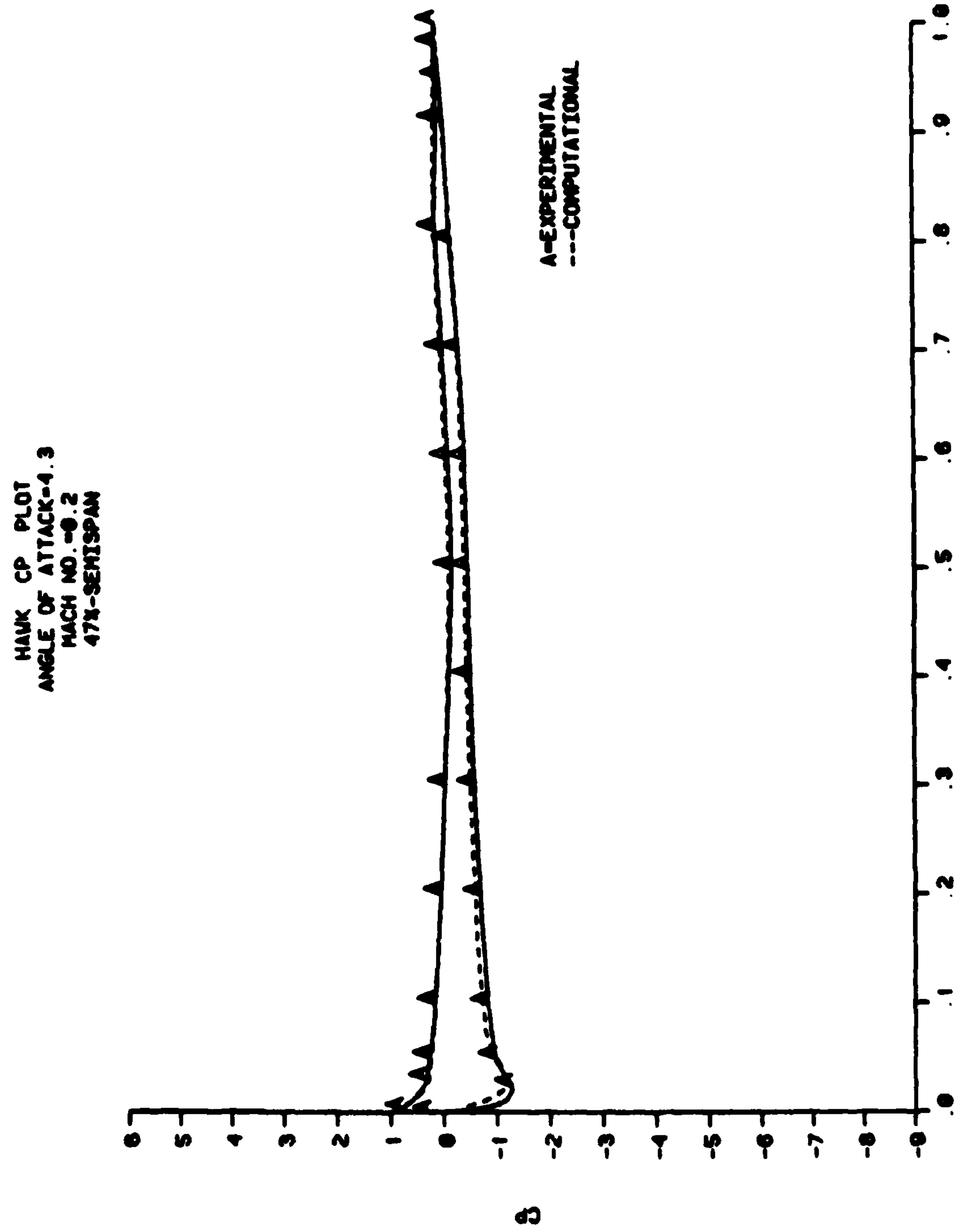

Figure 8. Comparison of CP Distribution at 47% Semi Span at 4° Angle of Attack

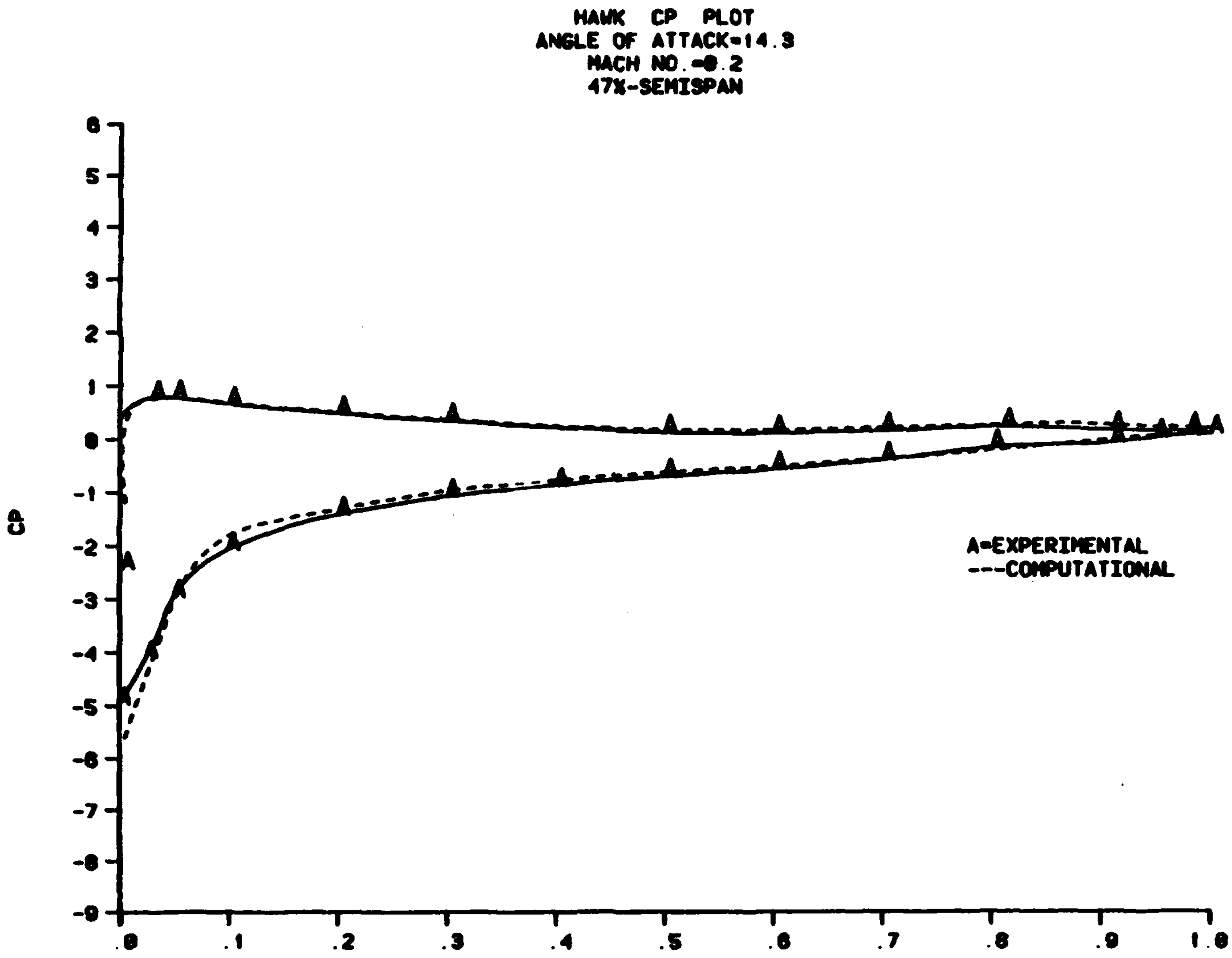

Figure 9. Comparison of CP Distribution at 47% Semi Span at 14° Angle of Attack

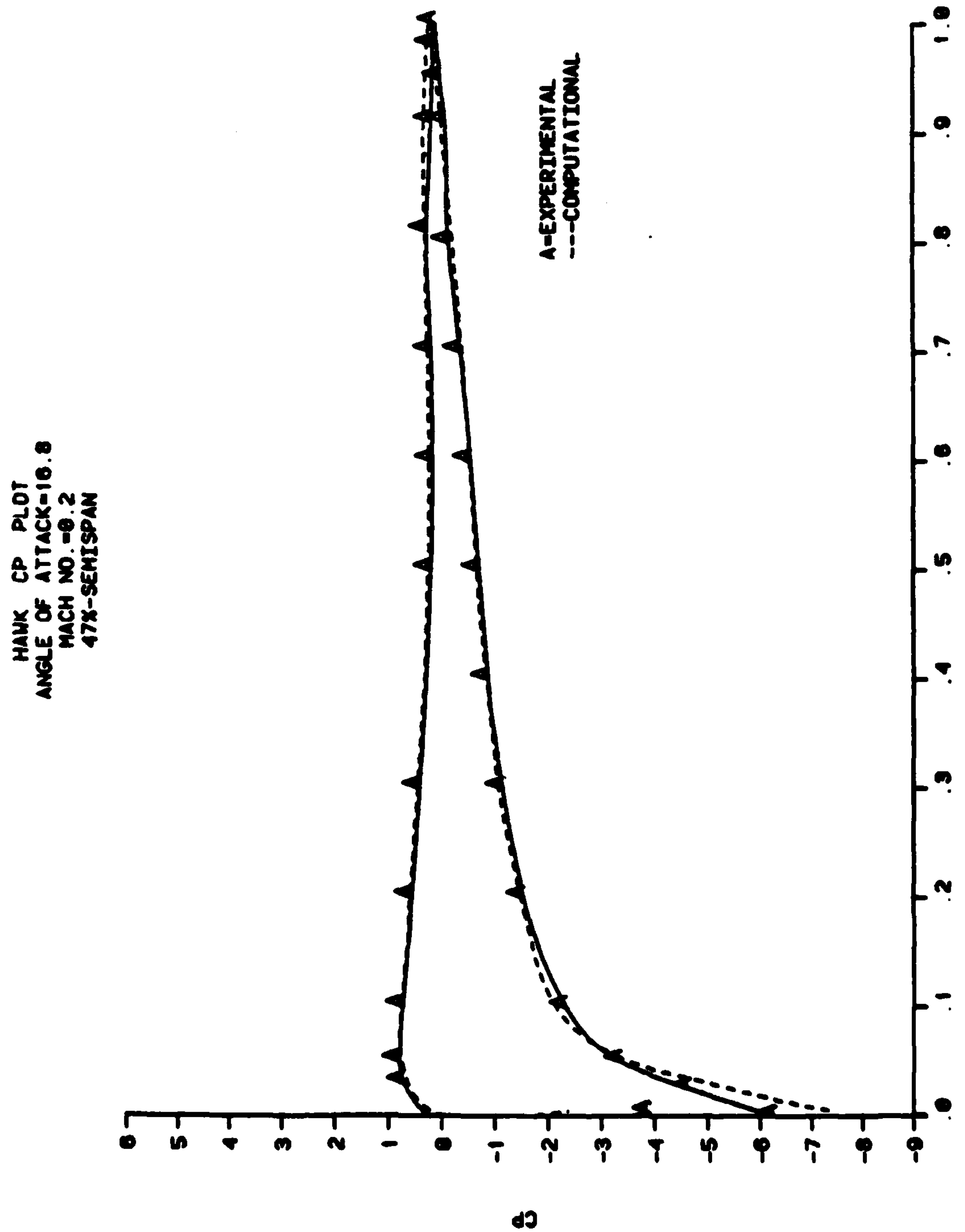

Figure 10. Comparison of CP Distribution at 47% Semi Span at 16.8° Angle of Attack

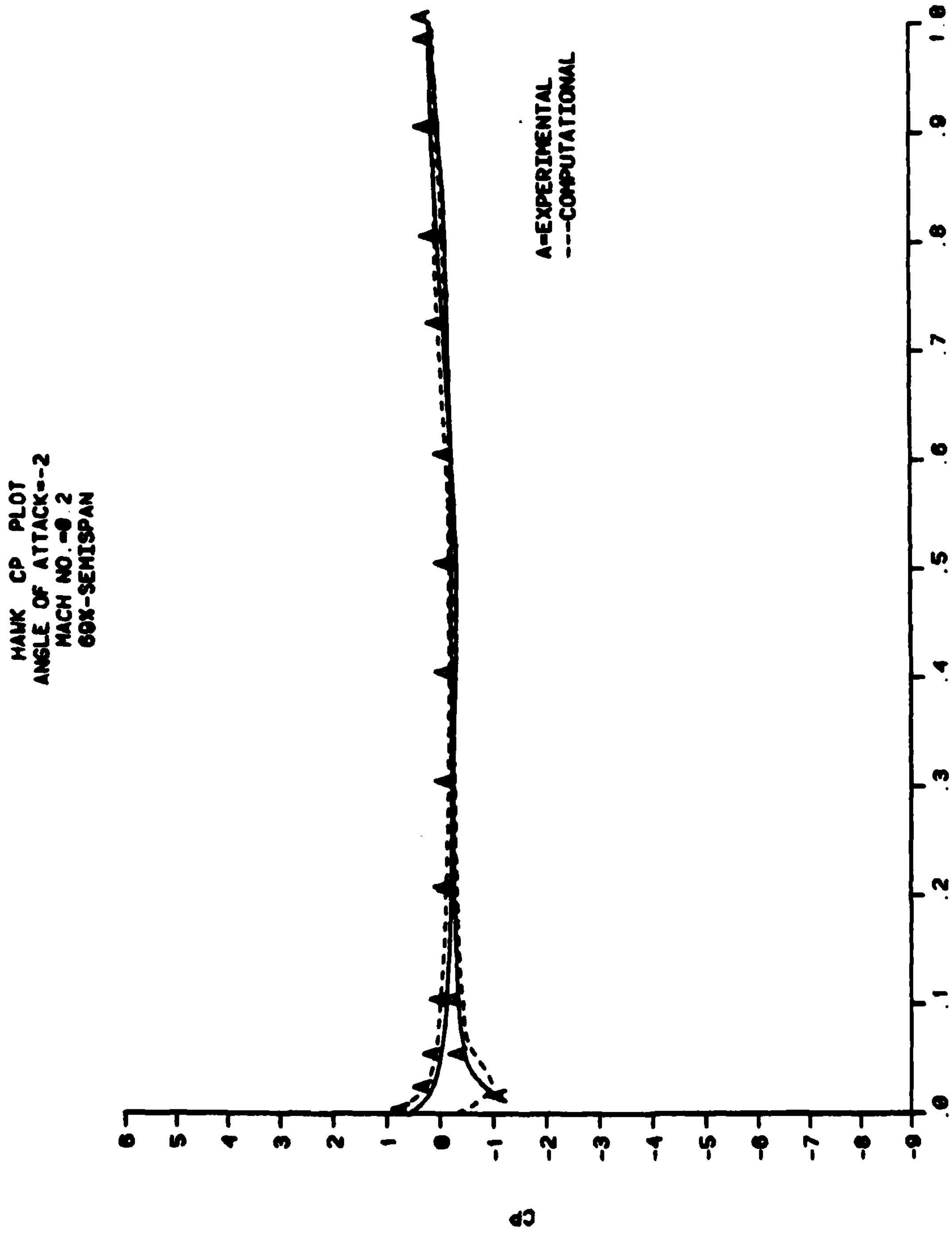

Figure 11. Comparison of CP Distribution at 69.5% Semi Span at -2° Angle of Attack

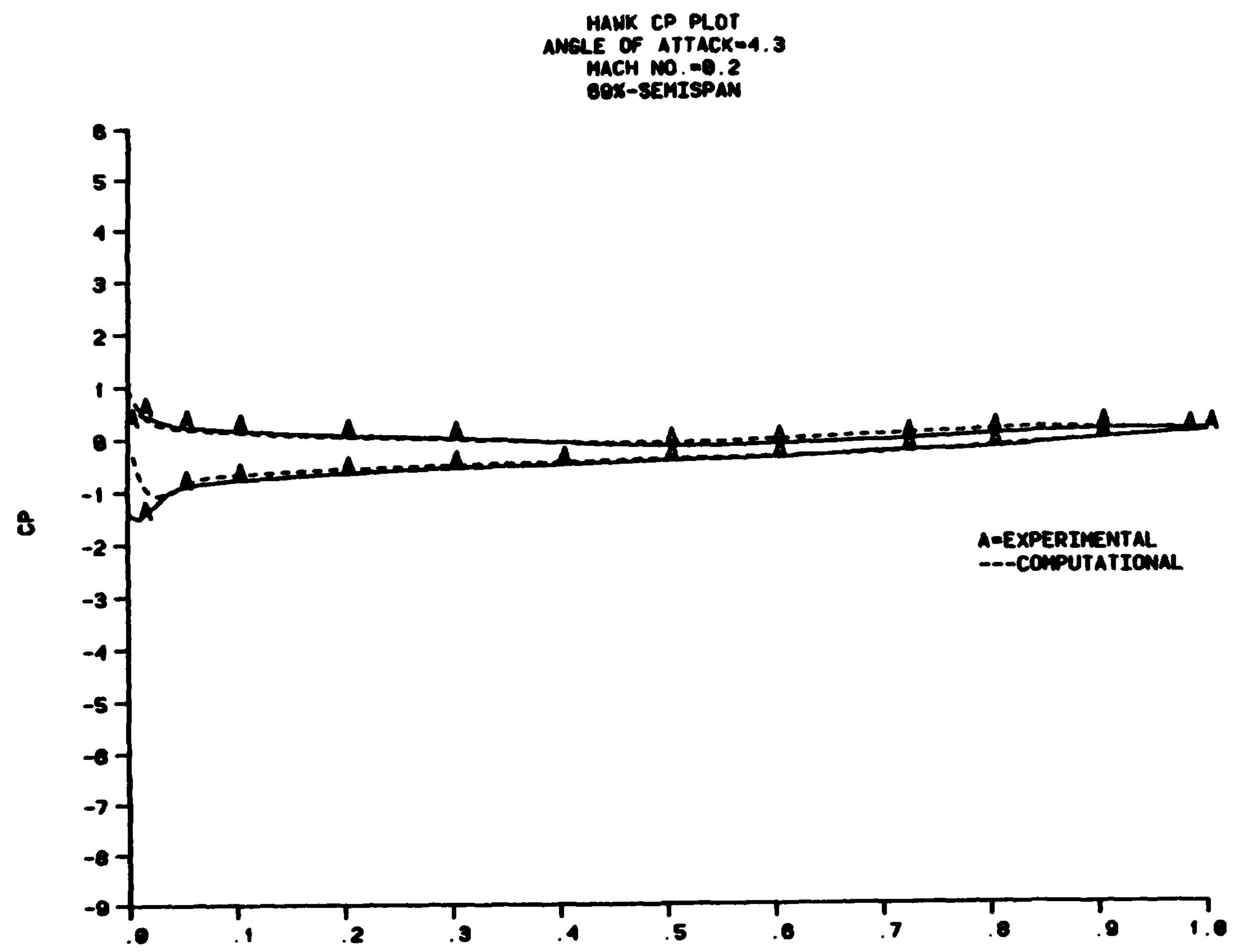

Figure 12. Comparison of CP Distribution at 69.5% Semi Span at 4^{O} Angle of Attack

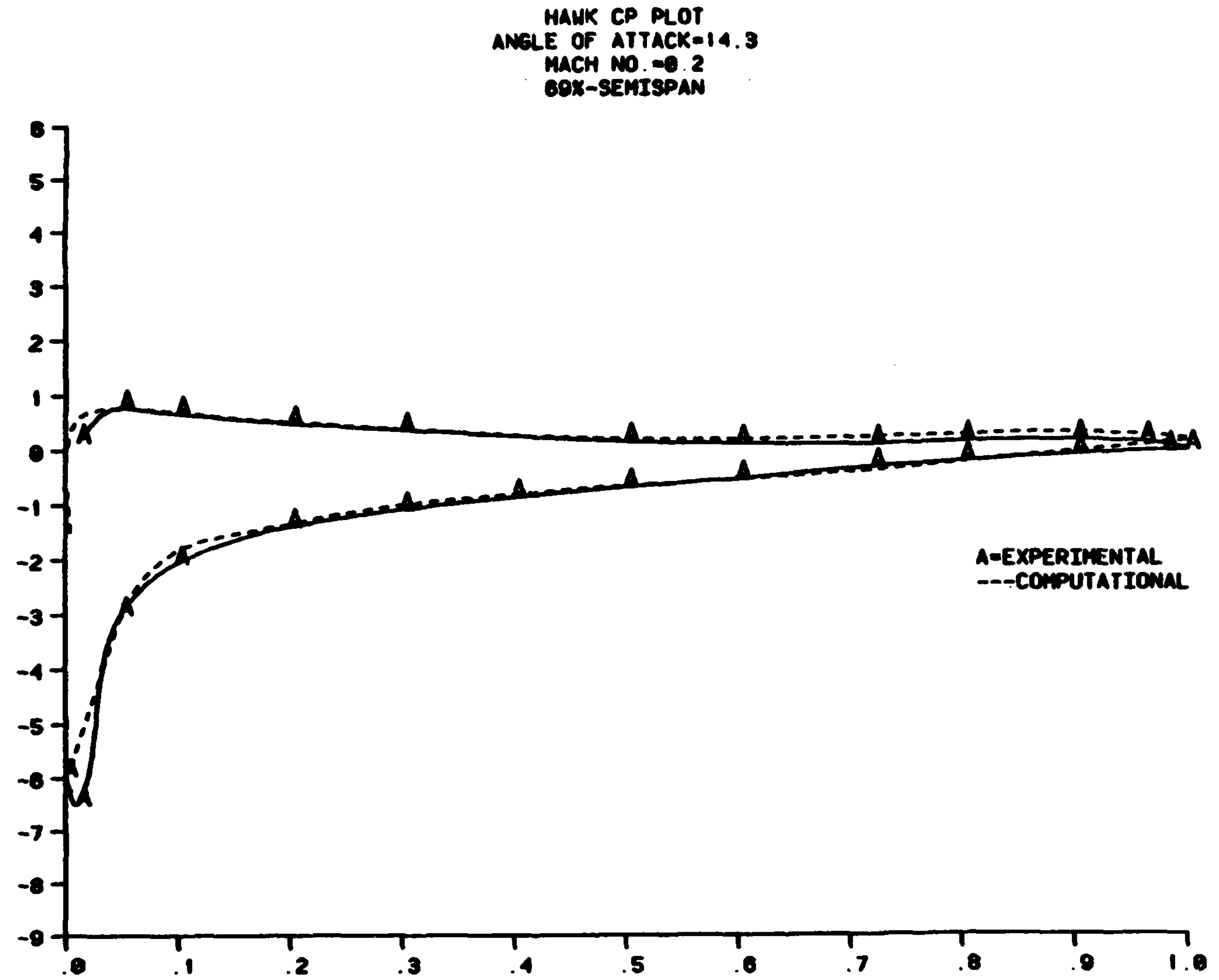

Figure 13. Comparison of CP Distribution at 69.5% Semi Span at 14° Angle of Attack

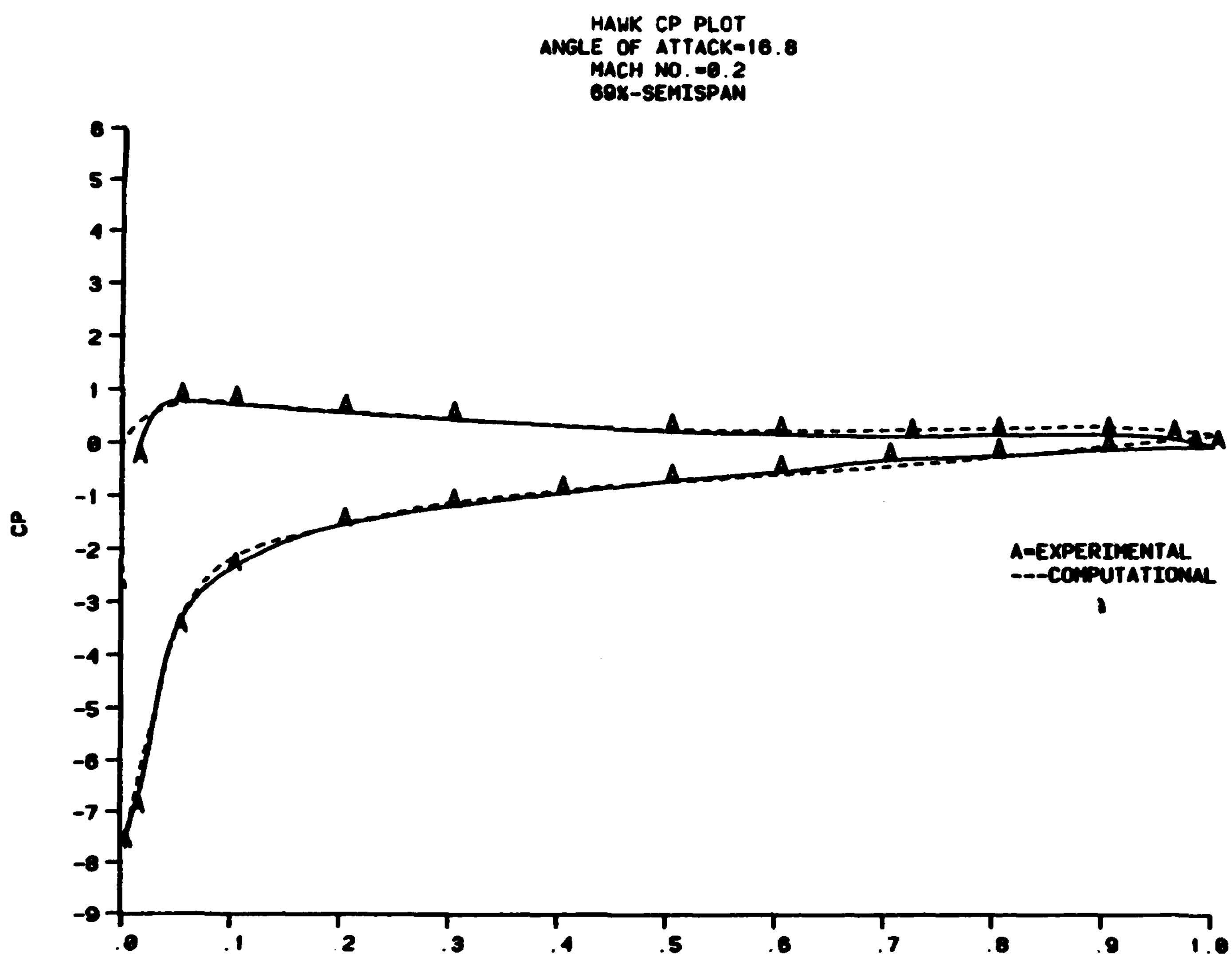

Figure 14. Comparison of CP Distribution at 69.5% Semi Span at 16.8° Angle of Attack

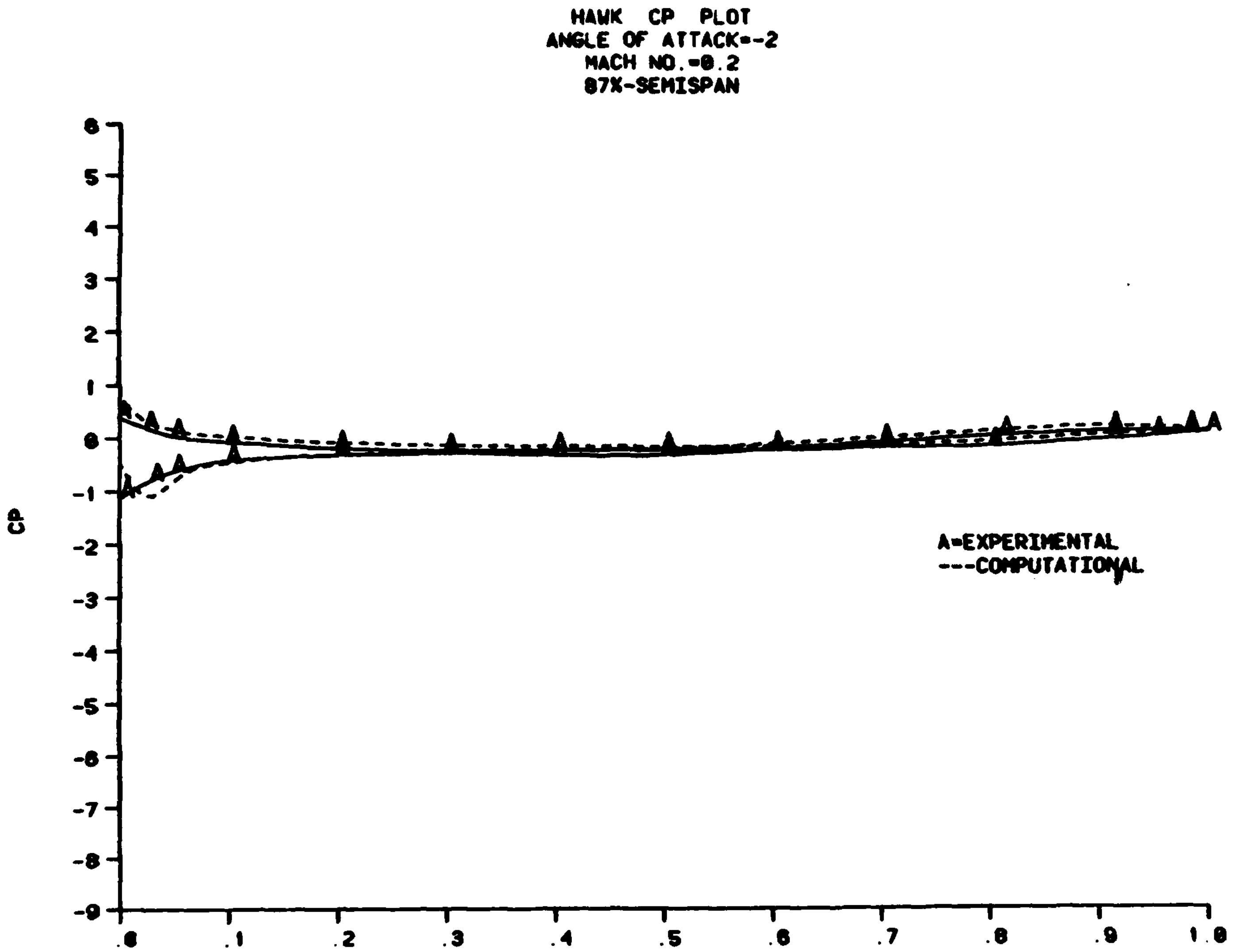

Figure 15. Comparison of CP Distribution at 87% Semi Span at -2° Angle of Attack

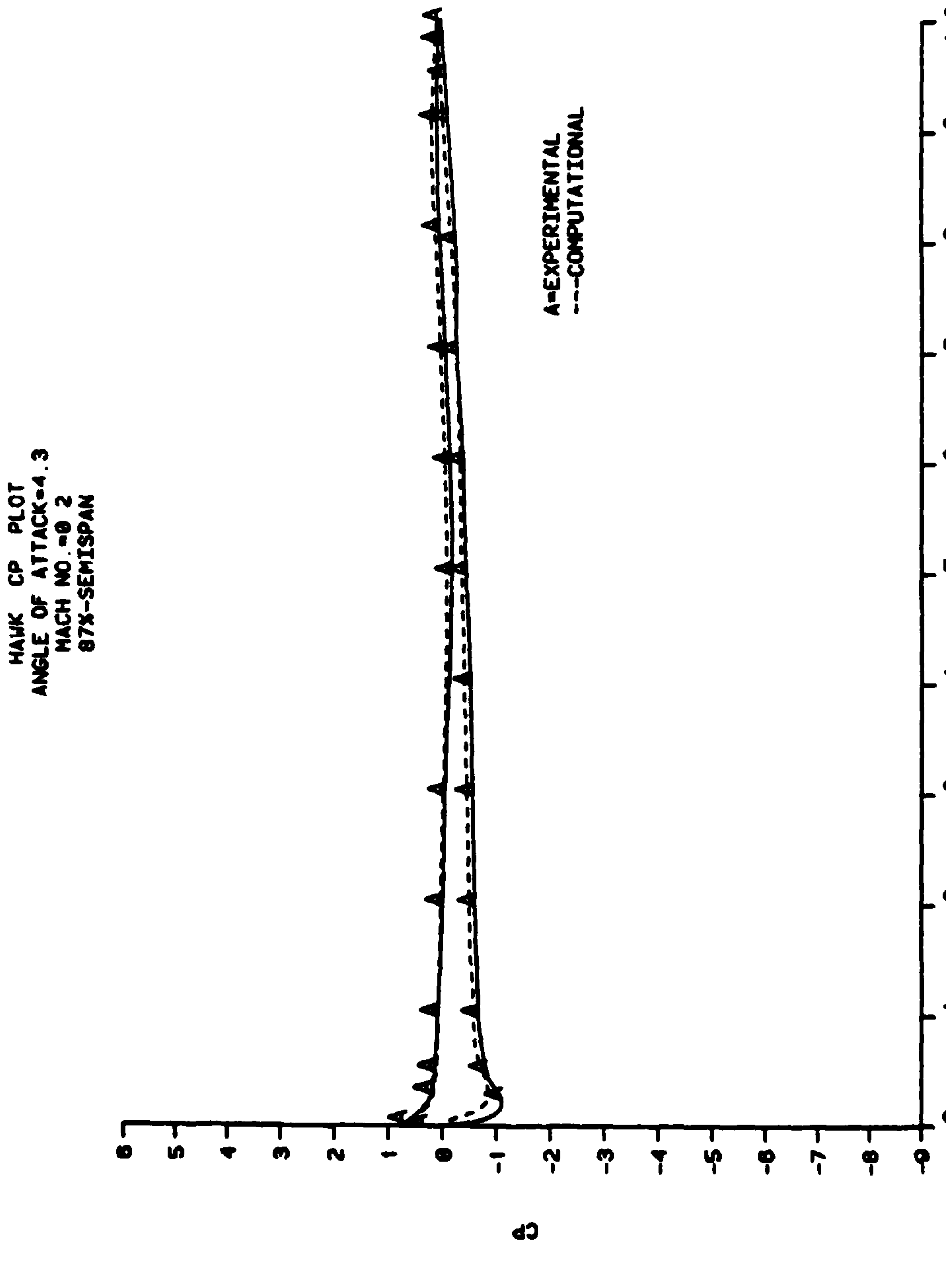

Figure 16. Comparison of CP Distribution at 87% Semi Span at 4° Angle of Attack

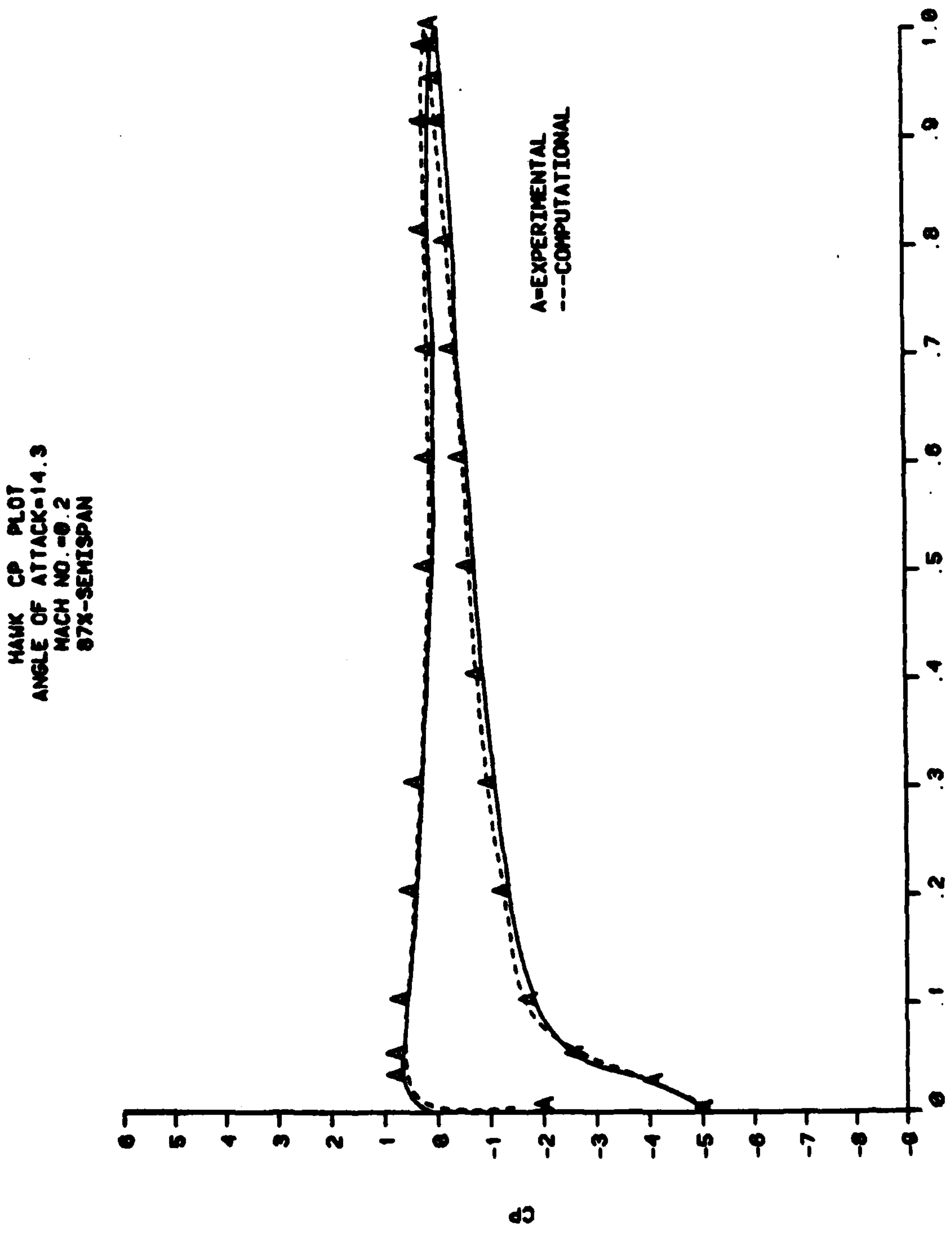

Figure 17. Comparison of CP Distribution at 87% Semi Span at 14° Angle of Attack

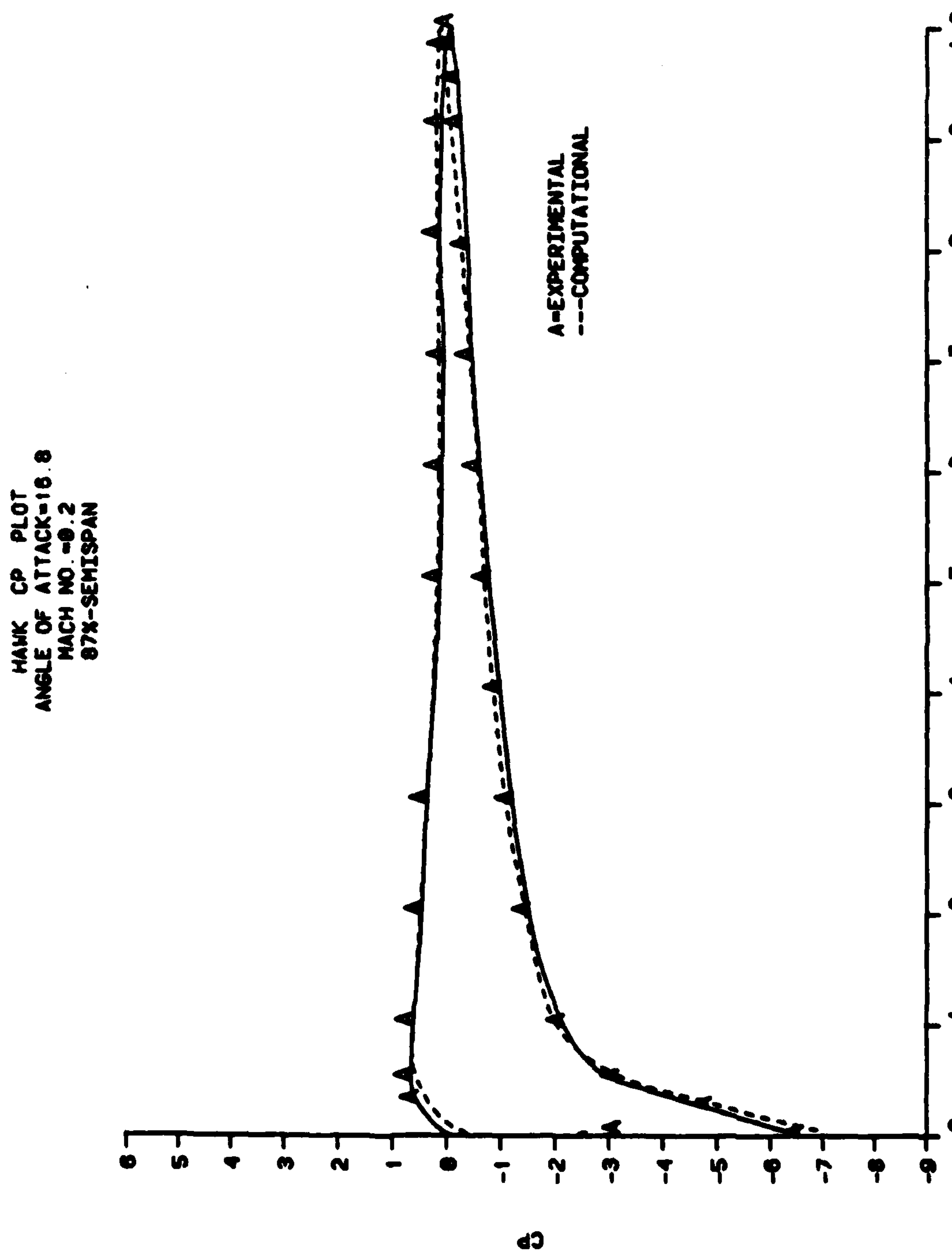

Figure 18. Comparison of CP Distribution at 87% Semi Span at 16.8^{o} Angle of Attack

REFERENCES

(a.) IR Work Unit GC144 "Systematic Application Study of Computational Aerodynamic Mathematical Models."

(b.) Magnus, A. E. and Epton, M.A., "PAN AIR – A Computer Program for Predicting Subsonic or Supersonic Linear Potential Flows About Arbitrary Configurations Using a Higher Order Panel Method, Vol. I, Theory Document (Version 1.0)." NASA CR-3251, 1980.

(c.) Sidwell, K. W., Baruah, P. K., and Bussoletti, J. E., "PAN AIR – A Computer Program for Predicting Subsonic or Supersonic Linear Potential Flows About Arbitrary Configurations Using a Higher Order Panel Method. Vol. II, User's Manual (Version 1.0)," NASA CR-3252, 1980.

(d.) Medan, R. T., Sidwell, K. W., Magnus, A. E. and Epton, M. A., "PAN AIR – A Computer Program for Predicting Subsonic or Supersonic Linear Potential Flows About Arbitrary Configurations Using a Higher Order Panel Method, Vol. III Case Manual (Version 1.0)," NASA CR-3253, 1981.

(e.) "Application of Panel Method to Airships," W. W. Tseng and R. E. Llorens', AIAA Lighter-Than-Air Systems Conference, July 1983.

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